POWER TRANSMISSION BELT AND BELT DRIVE SYSTEM WITH THE SAME

BACKGROUND OF THE INVENTION

(a) Field of the Invention

This invention relates to power transmission belts and belt drive systems with the same.

(b) Description of the Prior Art

V-ribbed belts are power transmission belts combining the flexibility of flat belts and the high power transmission capacity of V-belts, and are widely used, for example, as automotive accessory drive belts. In a V-ribbed belt of such kind, in order to allow it to withstand a side pressure and enhance the resistance of the back face part to vertical cracking, the back face side of the belt body is covered with a plainly woven reinforced fabric. In the V-ribbed belt, as shown in Figure **11**, the reinforced fabric **30'** is normally disposed at the belt back face so that the directions of warps **31'** and wefts **32'** form equal angles with the widthwise direction of the belt.

In recent years, as belt drive systems for driving automotive accessories, serpentine drive type ones have been increasingly employed which drive a single V-ribbed belt wound about multiple pulleys. In some of such serpentine belt drive systems, in order to accommodate a V-ribbed belt even in their complicated layout, at least one of the multiple pulleys is formed of a flat pulley that makes contact with the belt back face.

When a flat pulley making contact with the belt back face is used, however, there arises a problem that abnormal noises occur between the belt back face and the flat pulley. In the conventional V-ribbed belt, as shown in Figure **11**, the plainly woven reinforced fabric **30'** is disposed at the belt back face so that the directions of warps **31'** and wefts **32'** form equal angles with the belt widthwise direction. As a result, yarn intersections **33'** of the warps and wefts which stand out from the belt surface form lines of bulges **34'**

extending in the belt widthwise direction, and the lines of bulges **34'** are arranged at even intervals in the belt lengthwise direction. Therefore, the lines of bulges **34'** each formed by consecutive yarn intersections **33'** in the belt widthwise direction periodically beat the flat pulley to produce abnormal noises.

A technique for solving the above problem is disclosed in Japanese Unexamined Patent Publication No. 2002-235805. In this technique, at least either the wefts or warps of the reinforced fabric are arranged at uneven intervals to locate the yarn intersections of the wefts and warps at uneven intervals in the belt lengthwise direction. Thus, the frequency of vibratile forces of the pulley in contact with the reinforced fabric is dispersed to reduce the peak vibration intensity. Further, in the technique, the angles of arrangement of the wefts and warps of the reinforced fabric with respect to the belt lengthwise direction are made different from each other to reduce the interval of the yarn intersections in the belt lengthwise direction. Thus, the frequency of vibratile forces of the pulley in contact with the reinforced fabric becomes a high frequency departing from the audio frequency range, thereby suppressing noises.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a power transmission belt that can suppress production of abnormal noises between the belt back face and the flat pulley and does not cause side tracking during belt run, and also to provide a belt drive system with the same.

To attain the above object, in the present invention, each of two directions of consecutive yarn intersections of the warps and wefts formed to stand out from the belt surface, i.e., each of the directions in which lines of bulges formed of the yarn intersections extend, makes a certain angle with the belt widthwise direction. Thus, the lines of bulges make gradual contact in their lengthwise directions with the flat pulley to prevent the lines of bulges from periodically beating the flat pulley, which prevents the occurrence of

abnormal noises between the belt back face and the flat pulley. Furthermore, the reinforced fabric is disposed at the belt back face so that the directions of each warp and weft make equal angles with the belt widthwise direction. Therefore, the action of the belt traveling in the direction of the warps and the action of the belt traveling in the direction of the wefts counteract each other, thereby preventing the occurrence of belt side tracking.

More specifically, in a power transmission belt aiming toward attainment of the above object, the back face side of a belt body is covered with a reinforced fabric woven with warps and wefts. Furthermore, in the reinforced fabric, the direction of warps and the direction of wefts make equal angles with a widthwise direction of the belt, and each of two directions of consecutive yarn intersections of the warps and wefts formed to stand out from the belt surface makes a certain angle with the widthwise direction of the belt.

When each of the directions in which lines of bulges formed of the consecutive yarn intersections extend makes a certain angle with the belt widthwise direction, there arises no abnormal noises that would occur, previously, in the case where the direction in which the lines of bulges extend matched the belt widthwise direction. Furthermore, as the angle that the direction of the lines of bulges makes with the belt widthwise direction is increased, the lines of bulges have a stronger tendency to make gradual contact in their lengthwise directions with the flat pulley, whereby the contact is made more smoothly and therefore sounds themselves during belt run can be suppressed to a smaller extent. To be more specific, as shown in Test Evaluations described later, the smaller one of the angles that the two directions of the lines of bulges make with the belt widthwise direction is preferably 5° or more. When this angle exceeds 20°, there arises an inconvenience that belt side tracking during belt run is increased.

Therefore, in the power transmission belt, it is preferable that between the angles that the two directions of consecutive yarn intersections of the warps and wefts formed to stand out from the belt surface make with the widthwise direction of the belt, the smaller

angle is 5° to 20° inclusive.

Herein, when consecutive yarn intersections exist in only one direction, the angle that the direction of the consecutive yarn intersections makes with the widthwise direction of the belt means the above smaller angle.

In order to allow the direction of the lines of bulges to make a certain angle with the belt widthwise direction when the direction of warps and the direction of wefts make equal angles with the belt widthwise direction, it is conceivable that, for example, a woven fabric in which warps are different in yarn density from wefts or a rib weave fabric is used as the reinforced fabric.

Therefore, in the power transmission belt, the reinforced fabric may be formed of a woven fabric in which warps are different in yarn density from wefts.

Alternatively, in the power transmission belt, the reinforced fabric may be formed of a rib weave fabric.

The flexural property of the belt is susceptible to the directions of warps and wefts constituting the woven fabric. To be more specific, as the directions in which the warps and wefts run in the fabric approach the belt lengthwise direction, the belt stiffness becomes higher. Thus, increased bending loss provides reduced power transmission efficiency and increased heat production, resulting in low flexural fatigue resistance. In order to ensure the proper, low flexural stiffness, it is desirable that each of the angles that the direction of warps and the direction of wefts make with the widthwise direction of the belt is smaller than 40°.

Therefore, in the power transmission belt, each of the angles that the direction of warps and the direction of wefts make with the widthwise direction of the belt is preferably smaller than 40°.

No special limitation is imposed on the type of the power transmission belt. For example, the power transmission belt may be a V-belt or a V-ribbed belt. However, a V-ribbed belt is normally used in a serpentine drive with a flat pulley making contact with

the belt back face.

Therefore, the power transmission belt is suitable when the belt body is a body of a V-ribbed belt.

A belt drive system to which the above power transmission belt is applied may be one in which the power transmission belt is wound around a plurality of pulleys and at least one of the plurality of pulleys is formed of a flat pulley that makes contact with the belt back face. According to such a belt drive system, production of abnormal noises can be suppressed effectively.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages will become apparent from the following detailed description with reference to the accompanying drawings:

Figure **1** is a perspective view of a V-ribbed belt according to Embodiment 1 of the present invention;

Figure **2** is a schematic front view of a reinforced fabric in Embodiment 1;

Figure **3** is a schematic front view of the back face of the V-ribbed belt according to Embodiment 1;

Figure **4** illustrates the layout of an accessory belt drive system according to Embodiment 1;

Figure **5** is a schematic front view of the back face of a V-ribbed belt according to Embodiment 2 of the present invention;

Figure **6** is a schematic front view of a reinforced fabric in Embodiment 2;

Figure 7 is a graph showing the relation between the angle (α) of the direction in which lines of bulges extend with respect to the belt widthwise direction and peak sound pressure;

Figure **8** illustrates the layout of a belt run tester for a sound test;

Figure **9** illustrates the layout of a belt run tester for a belt durability test;

Figure **10** is a graph showing the relation between sound frequency and sound pressure during belt run; and

Figure **11** is a schematic front view of the back face of a conventional V-ribbed belt.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the drawings.

Embodiment 1

Figure **1** shows a V-ribbed belt **B** according to Embodiment 1.

This V-ribbed belt **B** has a V-ribbed belt body **10**, a cord **20** embedded in the V-ribbed belt body **10** to form a spiral with certain pitches in the belt widthwise direction, and a reinforced fabric **30** disposed to cover the back face side of the V-ribbed belt body **10**.

The V-ribbed belt body **10** is made of a rubber composition such as chloroprene rubber (CR) or ethylene propylene diene monomer rubber (EPDM). The V-ribbed belt body **10** has a structure in which an adhesion rubber layer **11** containing the cord **20** embedded therein, a rib rubber layer **12** located under the adhesion rubber layer **11**, and a tension rubber layer **13** located over the adhesion rubber layer **11** to form a back face part of the belt are stacked into one. The rib rubber layer **12** located at the inner periphery side of the belt forms a part for coming into contact with the pulley to transmit power directly thereon. Therefore, in the rib rubber layer **12**, ridge-like ribs **12a** extending in the belt lengthwise direction are formed in parallel to each other and in alignment across the belt width, which ensures that the belt has a large surface area. The rib rubber layer **12** is reinforced by mixing therein short fibers **12b**, such as aramid fibers or nylon fibers, oriented in the belt widthwise direction. Exposed ones of the short fibers **12b** mixed into

the rib rubber layer **12** protrude from the belt surface.

The cord **20** is formed of twist yarns of aramid fibers or polyester fibers. To provide the cord **20** with the property of adhesion to the V-ribbed belt body **10**, it is subjected, prior to molding, to a series of treatments of soaking into a resorcinol-formaldehyde latex (RFL) liquid and heating, and/or a series of treatments of soaking into a rubber cement and drying.

As shown in Figure **2**, the reinforced fabric **30** is formed of a plain weave fabric consisting of warps **31** and wefts **32** in which ones are different in yarn density from the others (in Figure **2**, the weft **32** has a larger yarn density than the warp **31**). Note that if the warp and weft yarns have the same diameter, one has a diameter 1.7 to 5.0 times as large as the other. And, the plain weave fabric is produced so that the angle formed by the directions of each pair of warp **31** and weft **32** is 100° or more (its supplementary angle is 80° or less). To provide the reinforced fabric **30** with the property of adhesion to the V-ribbed belt body **10**, it is subjected, prior to molding, to a series of treatments of soaking into a resorcinol-formaldehyde latex (RFL) liquid and heating, a series of treatments of soaking into a rubber cement obtained by solving EPDM or the like in an organic solvent such as toluene and drying, a series of treatments of coating a rubber cement to its surface to be in contact with the V-ribbed belt body **10** and drying, or any possible combinations of them. As shown in Figure **3**, the reinforced fabric **30** is disposed at the belt back face so that the direction of the warps **31** and the direction of the wefts **32** make equal angles with respect to the belt widthwise direction. Since the warp **31** and the weft **32** differ in yarn density from each other, each of two directions of consecutive yarn intersections **33** of the warps **31** and wefts **32** formed to stand out from the belt surface, i.e., each of the directions in which lines of bulges **34** formed of the consecutive yarn intersections **33** extend, makes a certain angle with the belt widthwise direction. More specifically, the line of bulges **34** is a set of consecutive yarn intersections **33** on the diagonal line of grids formed by the warps **31** and wefts **32**. Furthermore, there are two types of lines of bulges **34**: those

which extend obliquely upward to the left at a relatively large angle with the belt widthwise direction, and those which extend obliquely upward to the left at a relatively small angle with the belt widthwise direction. Between the two types of lines of bulges **34**, those which have a smaller angle with the belt widthwise direction, i.e., the latter ones, have an angle (α) of 5° to 20° therewith. Moreover, in this reinforced fabric **30**, since the angle (θ) formed by the directions of each pair of warp **31** and weft **32** is 100° or more, the directions of the pair of warp **31** and weft **32** each make an angle of less than 40° with the belt widthwise direction.

In the V-ribbed belt **B** of this embodiment, the two directions in which the lines of bulges **34** extend each make a certain angle with the belt widthwise direction. Therefore, when the belt back face comes into contact with the flat pulley, each line of bulges **34** makes gradual contact in its longitudinal direction with the flat pulley. Thus, unlike the conventional technique, the flat pulley is not beaten periodically by the lines of bulges **34**, thereby preventing the occurrence of abnormal noises between the belt back face and the flat pulley. In addition, in this embodiment, the reinforced fabric **30** is disposed at the belt back face so that the direction of the warps **31** and the direction of the wefts **32** make equal angles with the belt widthwise direction. Therefore, the action of the V-ribbed belt **B** traveling in the direction of the warps **31** and the action of the V-ribbed belt **B** traveling in the direction of the wefts **32** counteract each other, thereby suppressing the occurrence of belt side tracking.

Furthermore, since the smaller one (α) of the angles that the directions of the lines of bulges **34** make with the belt widthwise direction is 5° or more, each line of bulges **34** has a strong tendency to make gradual contact in its longitudinal direction with the flat pulley, whereby the contact is made smoothly. Therefore, noises themselves during belt run can be suppressed to a small extent. In addition, since the angle (α) is not more than 20°, this suppresses side tracking of the moving belt in the belt widthwise direction.

Moreover, since each of the directions of the warp **31** and the weft **32** makes an

angle of less than 40° with the belt widthwise direction, the belt flexural property, i.e., the belt flexural stiffness, can be suppressed to a small extent. Therefore, the belt reduces bending loss to obtain a high power transmission efficiency and less heat production. As a result, the V-ribbed belt **B** has an excellent flexural fatigue resistance.

The above V-ribbed belt **B** can be fabricated by known belt fabrication methods.

Figure **4** shows the layout of an accessory belt drive system **40** of the serpentine drive type in an automotive engine using the V-ribbed belt **B**.

This layout of the accessory belt drive system **40** is formed by a crank shaft pulley **41**, an air conditioner pulley **42**, a water pump pulley **43**, an alternator pulley **44**, a power steering pulley **45**, and a tensioner pulley **46**. Among these pulleys, those other than the tensioner pulley **46** and the water pump pulley **43**, which are both flat pulleys, are all ribbed pulleys. The V-ribbed belt **B** is wound around the crank shaft pulley **41**, the air conditioner pulley **42**, the alternator pulley **44** and the power steering pulley **45** to make contact with the belt ribbed surface, and wound around the water pump pulley **43** and the tensioner pulley **46** to make contact with the belt back face.

Since the above V-ribbed belt **B** is used in this accessory belt drive system **40**, when the back face of the moving belt comes into contact with the tensioner pulley **46** and the water pump pulley **43** as flat pulleys, each line of bulges **34** constituted by the yarn intersections **33** of the warps **31** and wefts **32** makes gradual contact in its longitudinal direction with the pulleys. Therefore, unlike the conventional technique, the pulleys are not beaten periodically by the lines of bulges **34**, thereby preventing the occurrence of abnormal noises between the belt back face and each of the tensioner pulley **46** and the water pump pulley **43**.

In the accessory belt drive system **40** of this embodiment, the reinforced fabric **30** is disposed at the belt back face so that the direction of the warps **31** and the direction of the wefts **32** make equal angles with the belt widthwise direction. Therefore, the action of the V-ribbed belt **B** traveling in the direction of the warps **31** and the action of the

V-ribbed belt **B** traveling in the direction of the wefts **32** counteract each other, thereby suppressing the occurrence of belt side tracking.

Embodiment 2

Figure **5** shows the back face of a V-ribbed belt **B** according to Embodiment 2. Note that the same reference characters refer to the same parts as in Embodiment 1.

As shown in Figure **6**, the reinforced fabric **30** of the V-ribbed belt **B** is formed of a rib weave fabric produced so that the angle formed by the directions of each pair of warp **31** and weft **32** is 100° or more (its supplementary angle is 80° or less). To provide the reinforced fabric **30** with the property of adhesion to the V-ribbed belt body **10**, it is subjected, prior to molding, to a series of treatments of soaking into a resorcinol-formaldehyde latex (RFL) liquid and heating, a series of treatments of soaking into a rubber cement and drying, a series of treatments of coating a rubber cement to its surface to be in contact with the V-ribbed belt body **10** and drying, or any possible combinations of them. The rib weave fabric forming the reinforced fabric **30** is woven in weft rib weave that has a pattern in which the wefts **32** appear alternately on the front and back of the textile for every two warps **31** and another pattern in which the adjacent wefts **32** appear alternately on the front and back of the textile for every two warps **31** in the reversed manner. Needless to say, the reinforced fabric **30** may be woven in warp rib weave that has a pattern in which the warps **31** appear alternately on the front and back of the textile for every two wefts **32** and another pattern in which the adjacent warps **31** appear alternately on the front and back of the textile for every two wefts **32** in the reversed manner. As shown in Figure **5**, the reinforced fabric **30** is disposed at the belt back face so that the direction of the warps **31** and the direction of the wefts **32** make equal angles with the belt widthwise direction. Since a rib weave fabric is used as the reinforced fabric **30**, each of two directions of consecutive yarn intersections **33** of the warps **31** and wefts **32** formed to stand out from the belt surface, i.e., each of the directions

in which lines of bulges **34** extend, makes a certain angle with the belt widthwise direction. In this case, there are two types of lines of bulges **34**: those which extend obliquely upwardly leftward at a relatively large angle with the belt widthwise direction, and those which extend obliquely upwardly leftward at a relatively small angle with the belt widthwise direction. Between the two types of lines of bulges **34**, those which have a smaller angle with the belt widthwise direction, i.e., the latter ones, have an angle (α) of 5° to 20° therewith. Furthermore, in this reinforced fabric **30**, the angle (θ) formed by the directions of each pair of warp **31** and weft **32** is 100° or more. Therefore, the directions of the warp **31** and the weft **32** each make an angle of less than 40° with the belt widthwise direction.

The other structures are the same as those of Embodiment 1.

The V-ribbed belt **B** of this embodiment is also applicable to an accessory belt drive system **40** of the serpentine drive type in an automotive engine, like the V-ribbed belt of Embodiment 1.

The behaviors and effects are the same as those of Embodiment 1.

Other Embodiments

Though Embodiments 1 and 2 have described V-ribbed belts **B**, the present invention is not limited thereto. Included in power transmission belts of the present invention are any power transmission belts in which the back face side of a belt body is covered with a reinforced fabric, such as a V-belt.

Test Evaluations

(Test Evaluation 1)

<Test Evaluation Belt>

Prepared were reinforced fabrics formed of plain weave fabrics of eight types that are different from one another in the yarn densities of the warp and weft. Then, V-ribbed

belts made of EPDM using the respective reinforced fabrics were fabricated. At the time, the back face of each V-ribbed belt is covered with the reinforced fabric so that the direction of the warps and the direction of the wefts have equal angles with the belt widthwise direction. The resultant eight V-ribbed belts differed from one another in the angle that each of two directions of consecutive yarn intersections of the warps and wefts formed to stand out from the belt surface, i.e., each of the directions in which lines of bulges formed of the yarn intersections extend, makes with the belt widthwise direction. The eight V-ribbed belts were used as test evaluation belts.

<Test Evaluation Method>

The eight test evaluation belts were run, under the same conditions, over a belt drive system which is provided with a flat pulley making contact with the belt back face, and their maximum sound pressures were measured during belt run.

<Test Evaluation Results>

Figure 7 shows the relation between the smaller one (α) of the angles that two directions of lines of bulges make with the belt widthwise direction and peak sound pressure. In the figure, when the belt back face is viewed from the front with the belt running upward, the negative sign of the angle (α) indicates that the direction of lines of bulges is upward to the right, while the positive sign of the angle (α) indicates that the direction of lines of bulges is downward to the right. When the angle that the direction of lines of bulges makes with the belt widthwise direction is 0°, this means that the former matches the latter.

As seen from Figure 7, when the direction of lines of bulges matches the belt widthwise direction, the peak sound pressure reaches a maximum value. This is probably because in the case where the direction of lines of bulges matches the belt widthwise direction, the sounds produced by the lines of bulges periodically beating the pulley are observed as particular peak sound pressure levels.

Further, it can be seen from Figure 7 that as the angle (α) which the direction of

lines of bulges makes with the belt widthwise direction is increased, sound becomes smaller. This is probably because in the case where the angle (α) which the direction of lines of bulges makes with the belt widthwise direction is increased, the lines of bulges have a stronger tendency to make gradual contact in their lengthwise directions with the flat pulley, whereby the contact is made smoothly and therefore sounds themselves during belt run can be suppressed to a small extent.

When the angle (α) is in the range from 0° to 5° or 8°, the peak sound pressure level is reduced to a relatively great extent. However, even if the angle (α) is increased over the range, the peak sound pressure level is not reduced to a much greater extent. Therefore, it is desirable that the angle (α) which the direction of lines of bulges makes with the belt widthwise direction is at least 5°, preferably at least 8°. Note that in consideration of preventing large belt side tracking in the belt widthwise direction during belt run, the angle (α) is preferably 20° or less.

(Test Evaluation 2)

<Test Evaluation Belt>

V-ribbed belts as shown in the following examples were fabricated. The structures of these belts are also shown in Table 1.

-Example 1-

As a reinforced fabric, use was made of a plain weave fabric which is formed of mutually crosswise (β = 90°) running warps and wefts each made by twisting two 300-dtex polyester/cotton blended yarns and has a warp yarn density of 90 yarns/5 cm and a weft yarn density of 50 yarns/5 cm. A V-ribbed belt of EPDM (having seven ribs) was fabricated as Example 1 by covering the belt back face with the reinforced fabric so that each of the directions of the warp and the weft makes an angle of 45° with the belt widthwise direction. In the back face of Example 1 V-ribbed belt, between angles that two directions of consecutive yarn intersections of the warps and wefts formed to stand out

from the belt surface, i.e., two directions in which lines of bulges formed of the yarn intersections extend, make with the belt widthwise direction, the smaller angle (α) was 7°, and the pitch of the lines of bulges was 0.86 mm.

-Example 2-

As a reinforced fabric, use was made of a weft rib weave fabric which is formed of mutually crosswise ($\beta = 90°$) running warps and wefts each made by twisting two 300-dtex polyester/cotton blended yarns and has a warp yarn density of 90 yarns/5 cm and a weft yarn density of 90 yarns/5 cm. A V-ribbed belt of EPDM (having seven ribs) was fabricated as Example 2 by covering the belt back face with the reinforced fabric so that each of the directions of the warp and the weft makes an angle of 45° with the belt widthwise direction. In the back face of Example 2 V-ribbed belt, between angles that two directions in which lines of bulges extend make with the belt widthwise direction, the smaller angle (α) was 14°, and the pitch of the lines of bulges was 1.17 mm.

-Example 3-

As a reinforced fabric, use was made of a plain weave fabric having the same structure as the reinforced fabric in Example 1 except that the angle (β) formed by the directions of warps and wefts was 120°. A V-ribbed belt of EPDM (having seven ribs) was fabricated as Example 3 by covering the belt back face with the reinforced fabric so that each of the directions of the warp and the weft makes an angle of 30° with the belt widthwise direction. In the back face of Example 3 V-ribbed belt, between angles that two directions in which lines of bulges extend make with the belt widthwise direction, the smaller angle (α) was 8°, and the pitch of the lines of bulges was 0.95 mm.

-Example 4-

As a reinforced fabric, use was made of a weft rib weave fabric having the same structure as the reinforced fabric in Example 2 except that the angle (β) formed by the directions of warps and wefts was 120°. A V-ribbed belt of EPDM (having seven ribs) was fabricated as Example 4 by covering the belt back face with the reinforced fabric so

that each of the directions of the warp and the weft makes an angle of 30° with the belt widthwise direction. In the back face of Example 4 V-ribbed belt, between angles that two directions in which lines of bulges extend make with the belt widthwise direction, the smaller angle (α) was 8.5°, and the pitch of the lines of bulges was 0.95 mm.

-Example 5-

As a reinforced fabric, use was made of a plain weave fabric which is formed of mutually crosswise (β = 90°) running warps and wefts each made by twisting two 300-dtex polyester/cotton blended yarns and has a warp yarn density of 80 yarns/5 cm and a weft yarn density of 80 yarns/5 cm. A V-ribbed belt of EPDM (having seven ribs) was fabricated as Example 5 by covering the belt back face with the reinforced fabric so that each of the directions of the warp and the weft makes an angle of 45° with the belt widthwise direction. In the back face of Example 5 V-ribbed belt, one of two directions in which lines of bulges extend matched the belt widthwise direction, and the pitch of the lines of bulges was 0.88 mm.

-Example 6-

As a reinforced fabric, use was made of a plain weave fabric having the same structure as the reinforced fabric in Example 5 except that the fabric has a warp yarn density of 90 yarns/5 cm and a weft yarn density of 90 yarns/5 cm and that the angle (β) formed by the directions of warps and wefts was 120°. A V-ribbed belt (having seven ribs) was fabricated as Example 6 by covering the belt back face with the reinforced fabric. In the back face of Example 6 V-ribbed belt, one of two directions in which lines of bulges extend matched the belt widthwise direction, and the pitch of the lines of bulges was 0.63 mm.

Table 1

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6
Warp yarn type	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended
Weft yarn type	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended	Polyester/ Cotton Blended
Warp weight (dtex/2s)	300	300	300	300	300	300
Weft weight (dtex/2s)	300	300	300	300	300	300
Weave	Plain	Rib	Plain	Rib	Plain	Plain
Warp density (yarns/5 cm)	90	90	90	90	80	90
Weft density (yarns/5 cm)	50	90	50	90	80	90
Bulge line pitch (mm)	0.86	1.17	0.95	0.95	0.88	0.63
α (degrees)	7	14	8	8.5	0	0
β (degrees)	90	90	120	120	90	120
Belt material	EPDM	EPDM	EPDM	EPDM	EPDM	EPDM
Periodic sound pressure peak (dB)	Null	Null	Null	Null	70.8	61.3
Frequency at sound pressure peak (Hz)	Null	Null	Null	Null	7000	9630
Durability	98	101	109	112	100	108

<Test Evaluation Method>

-Sound Test during Belt Run-

As shown in Figure **8**, a belt run tester **80** used in this test includes a drive pulley **81** and a driven pulley **82** which are a pair of 60 mm diameter flat pulleys spaced away from each other. A microphone **83** for sound pickup is placed at a position 20 mm away from a belt delivery part of the driven pulley **82**, and is connected to analysis equipment **84** for sound analysis.

In a run test, each of the V-ribbed belts **B** of the above examples was wound around the drive pulley **81** and the driven pulley **82** of the belt run tester **80** to allow the

belt back face to come into contact with the pulley surfaces, a load was imposed on the driven pulley **82** by a set weight **SW** of 686 N to pull the driven pulley **82** backward, and the drive pulley **81** was then rotated at 2000 rpm. Under these conditions, sounds during the belt run were picked up by the microphone **83** and the sounds picked up were analyzed by the analysis equipment **84**.

-Belt Durability Test-

As shown in Figure **9**, a belt run tester **90** used in this test includes a drive pulley **91** which is a 120 mm diameter ribbed pulley, a first driven pulley **92** which is a 120 mm diameter ribbed pulley disposed above the drive pulley **91**, a second driven pulley which is a 45 mm diameter ribbed pulley disposed rightward of and at a height intermediate the drive and first driven pulleys **91** and **92**, and an idler pulley **94** which is a 85 mm diameter flat pulley disposed at the same height as the second driven pulley **93**, to the upper right of the drive pulley **91** and to the lower right of the first driven pulley **92** to form a belt winding angle of 120°.

In a run test, each of the V-ribbed belts **B** of the above examples was wound around the drive pulley **91** and the first and second driven pulleys **92** and **93** of the belt run tester **90** to allow the ribs to come into contact with the pulley surfaces, and also wound around the idler pulley **94** to allow the belt back face to come into contact with the pulley surface, a load was imposed on the second driven pulley **93** by a set weight **SW** of 559 N for every three ribs to pull the second driven pulley **93** backward, a 8.8 kW load was concurrently imposed on the first driven pulley **92**, and the drive pulley **91** was rotated at 4900 rpm in an atmosphere of 100°C. Under these conditions, the time from the start of the run until the production of a crack in any one of the ribs was measured.

<Text Evaluation Results>

-Sound Test during Belt Run-

Figure **10** shows the relation between sound frequency and sound pressure during belt run. The peak sound pressures of periodic sounds and the frequencies at sound

pressure peaks are shown in Table 1.

According to Figure **10** and Table 1, the general tendencies of Examples 1 to 6 approximate one another. It can be seen that in the case of Example 5, a particular prominent sound pressure peak of 70.8 dB exists at 7000 Hz, and in the case of Example 6, a particular prominent sound pressure peak of 61.3 dB exists at 9630 Hz. These peaks probably occur because in the cases of Examples 5 and 6, one of the directions in which the lines of bulges extend matches the belt widthwise direction and sounds produced by the lines of bulges in that direction periodically beating the pulley were observed. More specifically, in Example 5, since the pitch of the lines of bulges in that direction was 0.88 mm and the drive pulley of 60 mm diameter was rotated at 2000 rpm, there was obtained a calculation result that the lines of bulges periodically beat the pulley at a frequency of 7136 Hz. Likewise, in Example 6, since the pitch of the lines of bulges in that direction is 0.63 mm, the lines of bulges periodically beat the pulley at a frequency of 9967 Hz. Thus, the test results approximate the calculation results very much. By contrast, in each of Examples 1 to 4, the direction in which the lines of bulges extend makes a certain angle (α) with the belt widthwise direction, and the lines of bulges make gradual contact in their lengthwise directions with the flat pulley, which suppresses periodic beating of the lines of bulges on the flat pulley. Therefore, it is considered that there exist no particular prominent sound pressure peak that would appear in the cases of Examples 5 and 6.

Comparison among Examples 1 to 4 shows that Example 2 is generally lower in sound pressure than the other examples. The reason for this is considered as follows. While the angle (α) which the direction of lines of bulges makes with the belt widthwise direction in Example 2 is 14°, the angles (α) in Examples 1, 3 and 4 are 7°, 8° and 8.5°, respectively. Like the case of Test Evaluation 1, as the angle (α) which the direction of lines of bulges makes with the belt widthwise direction is increased, the lines of bulges have a stronger tendency to make gradual contact in their lengthwise direction with the flat pulley, whereby the contact is made more smoothly and therefore sounds themselves

during belt run can be suppressed to a smaller extent.

-Belt Durability Test-

The belt lives of the examples are relatively shown in Table 1 in which the run time of Example 5 is set at a reference value of 100.

Reference to Table 1 shows that in point of belt durability, Example 3, which uses the reinforced fabric in which the angle (β) formed by the directions of warps and wefts is 120°, i.e., the angle that each of the warp and weft makes with the belt widthwise direction is 30°, is superior to Example 1, which uses the reinforced fabric in which the angle (β) formed by the directions of warps and wefts is 90°, i.e., the angle that each of the warp and weft makes with the belt widthwise direction is 45°. The same goes for comparison between Examples 2 and 4. Also, though different in the warp and weft yarn densities from Examples 1 to 4, the same goes for comparison between Examples 5 and 6. The reason for this is considered as follows. The smaller the angle that each of the warp and weft makes with the belt widthwise direction is, the lower the belt flexural property or the belt flexural stiffness becomes, and therefore the less the bending loss is produced. Therefore, the V-ribbed belt obtains a high power transmission efficiency and produces less heat. As a result, the V-ribbed belt has an excellent flexural fatigue resistance.

The foregoing discloses and describes merely exemplary embodiments of the present invention. One skilled in the art will readily recognize, from such discussion and accompanying drawings and claims, that various changes, modifications and variations can be made therein without departing from the spirit and scope of the present invention.